APPENDIX D.1

OVERVIEW OF GROUNDWATER EVALUATION UNITS AND THE RATING PROCESS

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CHAPTER 1. Overview of Groundwater Evaluation Units and the Rating Process

The process developed as a general framework for binning EUs using the evaluation metrics has been applied to the Risk Review Project groundwater EUs considering three distinct potential impacts: 1) groundwater as a protected resource, 2) groundwater as a pathway to impact the Columbia River, and 3) impact from potential future sources (e.g., tank leaks) and current vadose zone contamination to groundwater and the Columbia River. The focus on the evaluation metrics allows for differentiation between potential groundwater-related risks from the EUs. This process does not concern itself directly with highly uncertain point estimates of risks and impacts often used for other analyses (e.g., performance or baseline risk assessments). The uncertainties associated with the analyses related to EUs become more tractable when evaluation metrics are considered in relative rather than absolute terms. A detailed description of the methodology used for rating risks to groundwater and the Columbia River is provided in the Methodology Report (CRESP 2015). Detailed results for each groundwater EU are provided in Appendices D.2 through D.6.

The evaluation metrics for risks to groundwater from current groundwater plumes and near surface or vadose zone sources are:

1. The estimated time interval until groundwater would be *impacted* by a primary contaminant where a current plume does not exist over the three evaluation periods. Groundwater is considered *impacted* when a primary contaminant concentration exceeds a threshold value, e.g., a drinking water standard or maximum contaminant level.
2. The estimated amount of groundwater (e.g., areal extent) currently *impacted* by the primary contaminants with existing plumes.
3. The *groundwater threat metric (GTM)*, defined as the volume of groundwater that could potentially be contaminated by the inventory of a primary contaminant from a source (be it groundwater plume, vadose zone contamination, tank, etc.) if it was found in the saturated zone at the WQS (e.g., drinking water standard) and in equilibrium with the soil. The GTM accounts only for 1) source inventory, 2) partitioning with the surrounding subsurface, and 3) the WQS. The GTM reflects a snapshot in time (assuming no loss by decay/degradation or dispersion, etc.) and does not account for differences in contaminant mobility or bulk groundwater flow.

The selected evaluation metrics for risks to the Columbia River from near surface, vadose zone, and groundwater contamination sources are:

1. The estimated time interval until the Columbia River is *impacted* over the three evaluation periods. The Columbia River is considered *impacted* when a primary contaminant concentration exceeds a benthic or free-flowing threshold value.
2. The ratio (R1) of the maximum primary contaminant concentration within the plume to the reference threshold screening value (e.g., Biota Concentration Guide for radionuclides or Ambient Water Quality Criterion for chemicals).
3. The ratio (R2) of the upper 95th percentile upper confidence limit on the log-mean plume concentrations to the reference threshold screening value.
4. For benthic impacts, the length of river shoreline estimated to be impacted by the plume above a reference threshold.
5. For riparian zone impacts, the area of the riparian zone estimated to be impacted by the plume above a reference threshold.

The primary contaminant groups used in this Risk Review Project are described in Table D.1, which categorizes them according to their mobility and persistence in the Hanford Site environment. The categorization was done on a relative basis among the primary contaminants. Mobility relates to the relative ability of the primary contaminant to be transported in the subsurface environment (as represented by the contaminant transport retardation factor, R) and is mainly a function of the contaminant's chemistry and sorption with the Hanford subsurface geology. For the radioactive contaminants, the persistence category is based on the radionuclide's half-life. The persistence category of the organic and inorganic contaminants is based on their chemical degradation and biodegradation potential. Chromium, being non-degrading and not radioactive, is classified as having a high persistence in the subsurface. For the purposes of this Risk Review Project, the primary contaminants were divided into four groups based on their persistence and mobility. Group A includes technetium-99, iodine-129, carbon-14, chlorine-36, hexavalent chromium, and carbon tetrachloride. Group B contains strontium-90, trichloroethylene (TCE), uranium, total chromium, and cyanide. Group C contains tritium, nitrate, and TPH-diesel. Group D contains cesium-137, americium-241, plutonium (all isotopes), europium (all isotopes), nickel (all isotopes), and mercury[1]. The groups are ranked relative to each other with Group A being the highest (highly mobile and highly persistent) and Group D being the lowest (low mobility and highly persistent) for the purpose of this Risk Review Project.

[1] Mercury (Hg) was not in the list of primary contaminants in the Methodology Report (CRESMP 2015) and has been added as a Group D contaminant. Cantrell, et al., (2007) report the partition coefficient (K_d) of mercury (Hg) for "a geochemical environment similar to that for the vadose zone at the Hanford Site" as determined by Del Debbio (1991) in the range of "236 to 1,910 mL/g for alluvium sediment and 81 to 998 for interbed sediment." Additionally, mercury has only sporadically been found in groundwater monitoring and has only very infrequently been measured above the DWS of 2 µg/L. Subsequently, no groundwater plumes have been drawn for mercury (DOE/RL-2016-09, Rev. 0). It, therefore, is reasonable to use the lowest value of 81 mL/g from Del Debbio (1991) in this Review as a reasonable (lower) bounding partition coefficient for mercury. This partition coefficient translates to a retardation factor (*R*) greater than 500 in all areas considered (CRESP 2015). Mercury is also persistent in the environment, which when combined with an R > 500, translates into mercury being categorized as a Group D primary contaminant.

Table D.1. Primary Contaminant Groups used in this Risk Review Project.[1]

Persistence	Mobility* Low (R>500)	Mobility* Medium (5<R<500)	Mobility* High (R<5)
Low		TPH-diesel	^3H_2O, NO_3
Medium	Cs-137, Am-241	Sr-90	CN, TCE
High	Pu, Eu, Ni, Hg (all isotopes)	U-Total, Cr-Total	Tc-99, I-129, C-14, Cl-36, Cr-VI, CCl_4

Group A Primary Contaminants
Group B Primary Contaminants
Group C Primary Contaminants
Group D Primary Contaminants

* Assume most mobile form of contaminant
R = retardation factor

The screening thresholds used in the Risk Review Project are provided in Table D.2. When considering groundwater as a protected resource, the drinking water standard is used as the screening threshold, except for Cr(VI), where a drinking water standard is not available, and a screening threshold of 48 µg/L is used. When considering impacts to the Columbia River, a combination of the ambient water quality criterion (AWQC) and the biota concentration guide (BCG) are used, whichever value is more stringent. However, for total uranium, the natural background groundwater concentration of uranium at 12.9 µg/L is used, which was greater than the Tier II screening concentration value (SCV) reported.

Table D.2. Thresholds Considered in the Risk Review Project for the Group A and B Primary Contaminants. The primary thresholds used in the analysis are indicated in the red boxes.

PC	Grp	WQS[a]	DWS	DOE DCS[b]	BCG[c]	AWQC[d]/SCV[e]
Tc-99	A	900 pCi/L	900 pCi/L	44000 pCi/L	667000 pCi/L	---
I-129	A	1 pCi/L	1 pCi/L	330 pCi/L	38400 pCi/L	---
C-14	A	2000 pCi/L	2000 pCi/L	62000 pCi/L	609 pCi/L	---
Cl-36	A	---	700 pCi/L	32000 pCi/L	15100 pCi/L	---
Cr-VI	A	10-48 µg/L[f]	---	Human Health	Benthic/ Riparian	10 µg/L[f]
CCl_4	A	3.4 µg/L[g]	5 µg/L			9.8 µg/L
Sr-90	B	8 pCi/L	8 pCi/L	1100 pCi/L	279 pCi/L	7 µg/L (Sr)
U(tot)	B	30 µg/L	30 µg/L	750 pCi/L (U-238)	224 pCi/L (U-238)	5-12.9 µg/L[h]
Cr(tot)	B	48 µg/L[f]	100 µg/L[f]	---	---	55 µg/L
CN	B	200 µg/L	200 µg/L	---	---	5.2 µg/L
TCE	B	4[g]- 5 µg/L	5 µg/L	---	---	47 µg/L

a. Water Quality Standard (WQS) from the 2015 Annual GW Report (DOE/RL-2016-09, Rev. 0). Some values vary by Interest Area (IA).
b. DOE Derived Concentration Standard (Ingested Water DCS from Table 5 in DOE-STD-1196-2011).
c. Biota Concentration Guide (BCG) from RESRAD-BIOTA v1.8 (consistent with DOE Technical Standard DOE-STD-1153-2002).
d. Ambient Water Quality Criterion (AWQC) (Table 6-1 in DOE/RL-2010-117, Rev. 0).
e. Tier II Screening Concentration Value (SVC) (http://rais.ornl.gov/documents/tm96r2.pdf) when AQWC not provided.
f. Different values tabulated for different GW IAs. 10 µg/L is the surface water standard for Cr-VI. 20 µg/L is the groundwater cleanup target for Cr-VI for interim remedial action. 48 µg/L is the MTCA groundwater cleanup standard. 100 µg/L is the DWS for total chromium.
g. Risk-based cleanup value from the ROD as reported in the 2015 Annual GW Report.
h. Uranium (total) screening values were 0.5 µg/L (RCBRA) and 5 µg/L (CRCRA). PNNL-17034 indicated background of ~5-12.9 µg/L (300-FF). CRCRA indicated effect levels span 3-900 µg/L reflecting considerable uncertainty in no-effect concentration.

General flow diagrams are provided that summarize the rating process used for evaluating 1) groundwater as a protected resource (Figure D.1-1), 2) groundwater as a pathway to impact the Columbia River (Figure D.1-2), and 3) impact from current vadose zone contamination (Figure D.1-1). Additional background information and more detailed discussion of the rating methodology is provided in the Methodology Report (CRESP 2015).

All groundwater data was reevaluated for the Final Report based on available 2015 data. Estimated plume areas, impacted shoreline lengths, and maximum well concentrations were taken from the 2015 Hanford Site Groundwater Monitoring Report (DOE/RL-2016-09, Rev 0). Well data was downloaded from HEIS (http://ehs.hanford.gov/eda/) for the CY 2015. The downloaded data were used to estimate the 95% upper confidence interval (UCL) about the log-transformed means in a manner equivalent to that described for the 2013 data described in the Methodology Report (CRESP 2015). Groundwater plume maps for 2015 were provided by PNNL, and the software application Photoshop was used with the maps as described in the Methodology Report (CRESP 2015) to estimate total and individual plume areas in the Central Plateau a manner that the groundwater plume inventories could be apportioned to

individual evaluation units. The Photoshop measured plume areas compared favorably with the 2015 Hanford Site Groundwater Monitoring Report values with one exception[2] and one special case[3].

Table D.3 shows the percentage of each saturated zone plume in the Central Plateau groundwater EUs assigned to non-groundwater EUs for A and B primary contaminants. The process of assignment was to utilize the 2015 Hanford Site Groundwater Monitoring Report (DOE/RL-2016-09, Rev 0) to assess which plumes or portions of plumes could be attributed to an EU source. This was done on an interest area by interest area basis because that is how the plume areas are reported in the Hanford Site Groundwater Monitoring Report. Individual plume area sizes within an interest area were measured using Photoshop and scaled relative to the total plume area to arrive at the percentage value. Not all rows sum to 100% because sources could not be determined for all plume areas.

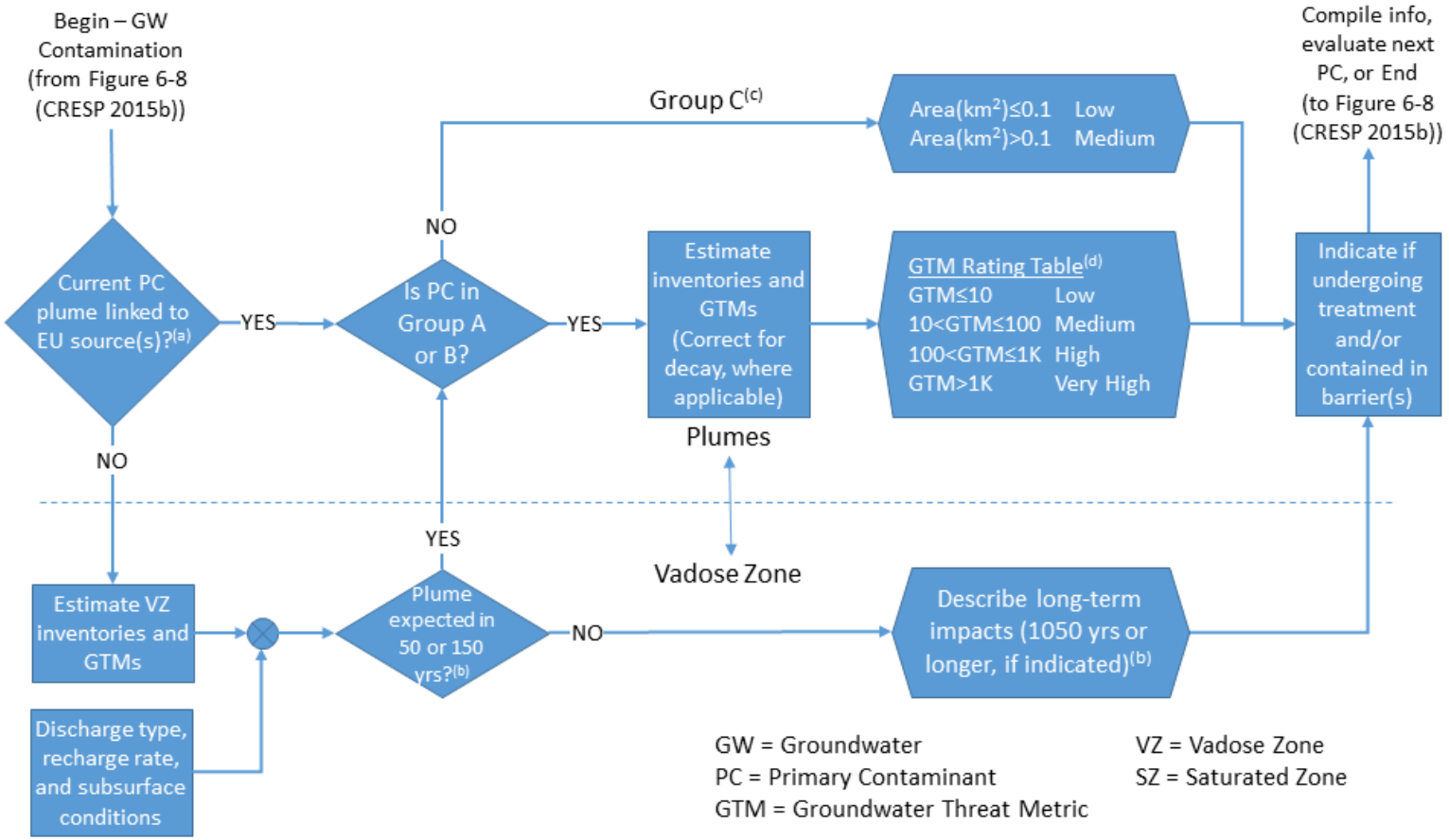
As described in the Methodology Report (CRESP 2015), this process cannot be done for the River Corridor groundwater EUs because not enough information is available.

[2] The 2015 Hanford Site Groundwater Monitoring Report (DOE/RL-2016-9, Rev. 0) reports a plume area for carbon tetrachloride as 18 km^2 at 5 µg/L. The Photoshop measurement was 17.1 km^2 at 5 µg/L. The value of 18 km^2 was used for this Review. Use of either value does not change the rating.

[3] There was no plume area for tricholoethene (TCE) at 5 µg/L provided in the 2015 Hanford Site Groundwater Monitoring Report (DOE/RL-2016-9, Rev. 0). The plume area used in this Review for TCE at 5 µg/L value was calculated via Photoshop and compares favorably with the data provided in the 2015 Hanford Site Groundwater Monitoring Report.

Table D.3. Percentage assignment of saturated zone inventory in each Central Plateau Interest Area to Evaluation Units as Sources for the saturated zone inventory.

Groundwater EU	Groundwater Interest Area	Primary Contaminant	Group	CP-LS-2	CP-LS-3	CP-LS-4	CP-LS-5	CP-LS-8	CP-LS-9	CP-LS-11	CP-TF-1	CP-TF-2	CP-TF-3	CP-TF-4	CP-TF-5	CP-TF-6	CP-TF-7
CP-GW-1	200-BP	I-129	A						91.4%	0.1%						8.5%	
CP-GW-1	200-BP	Tc-99	A					0.6%								94.1%	5.3%
CP-GW-1	200-BP	U-Total	B					34.5%								65.5%	
CP-GW-1	200-BP	Sr-90	B					10.1%		89.9%							
CP-GW-1	200-BP	CN	B													100.0%	
CP-GW-1	200-PO	I-129	A						91.4%	0.1%						8.5%	
CP-GW-1	200-PO	Sr-90	B						100.0%								
CP-GW-1	200-PO	Tc-99	A												39.2%		60.8%
CP-GW-1	200-PO	U-Total	B						100.0%								
CP-GW-2	200-UP	U-Total	B		97.6%		2.4%										
CP-GW-2	200-UP	Cr	B			99.0%	0.6%					0.5%					
CP-GW-2	200-UP	Cr-VI	A			99.0%	0.6%					0.5%					
CP-GW-2	200-UP	Tc-99	A		30.3%							62.5%		7.3%			
CP-GW-2	200-UP	I-129	A		0.7%	99.2%						0.1%					
CP-GW-2	200-UP	CCl4	A														
CP-GW-2	200-ZP	CCl4	A	95.0%			5.0%										
CP-GW-2	200-ZP	Cr	B								96.1%		3.9%				
CP-GW-2	200-ZP	Cr-VI	A								96.1%		3.9%				
CP-GW-2	200-ZP	I-129	A										41.7%				
CP-GW-2	200-ZP	Tc-99	A								46.2%		53.8%				
CP-GW-2	200-ZP	TCE	B														
CP-GW-2	200-ZP	U-Total	B														



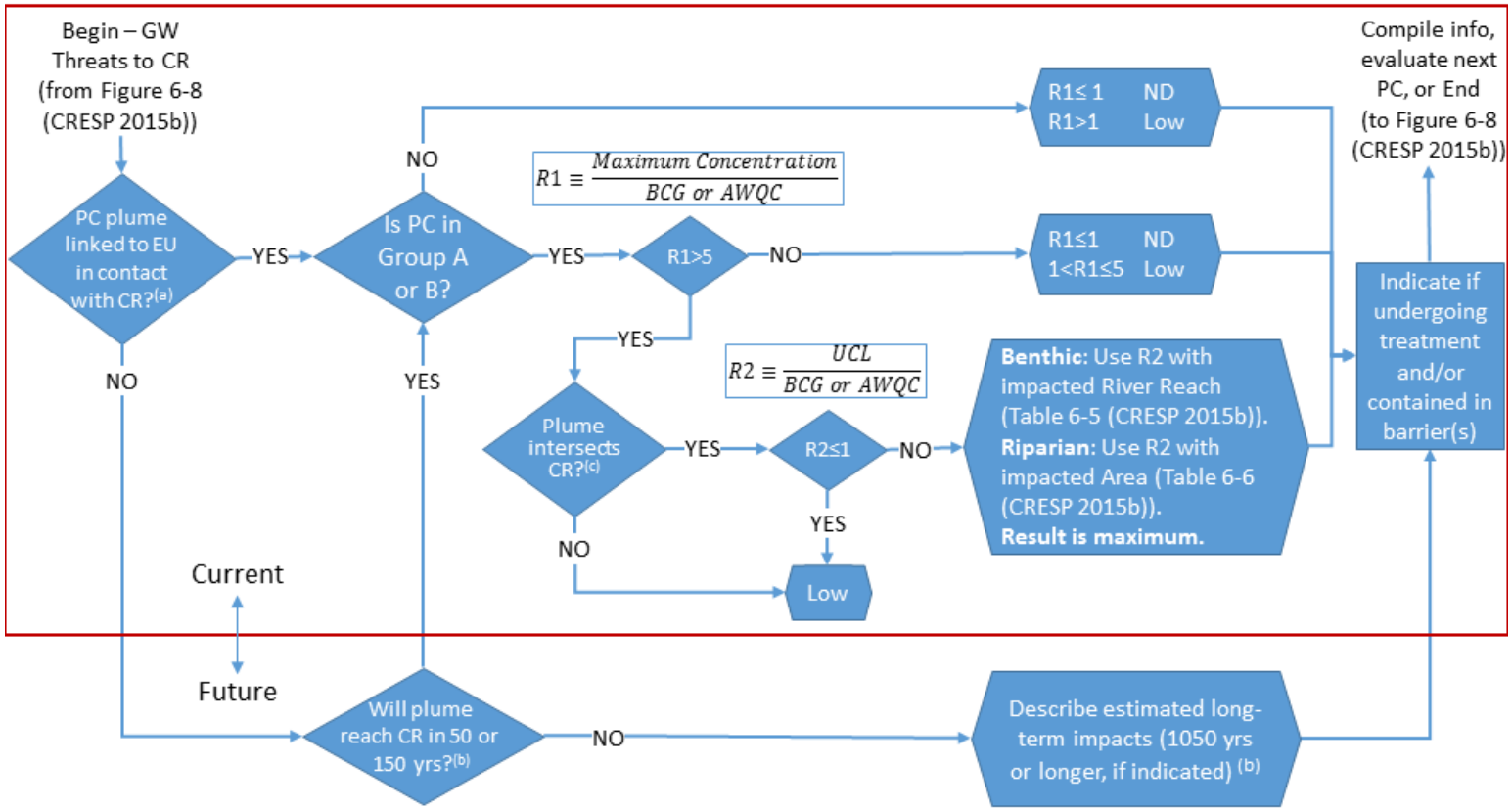
a. Based on plume area above a threshold (e.g., Water Quality Standard (WQS) from 2015 Annual GW Monitoring Report (DOE/RL-2016-09 Rev. 0)). Note plume areas and corresponding estimated plume volumes are (highly) positively correlated.

b. Use available information (e.g., environmental impact statements, risk assessments) to evaluate.

c. Note, no Group D contaminants have been identified as groundwater threats (CRESP 2015b).

d. GTM Rating Table for Group A and B PCs (Table 6-3 (CRESP 2015b)).

Figure D.1-1. Decision logic for characterizing threats to groundwater as a protected resource with respect to existing groundwater contamination and vadose zone contamination. Note: No Group D contaminants have been identified as groundwater threats.



PC = Primary Contaminant
GTM = Groundwater Threat Metric
UCL = Upper 95% confidence limit (log-mean)

VZ = Vadose Zone
CR = Columbia River

AWQC = Ambient Water Quality Criterion (chemicals)
BCG = Biota Concentration Guide (radionuclides)
ND = Not discernible

a. Based on plume area above a threshold (e.g., Water Quality Standard (WQS) from 2015 Annual GW Monitoring Report (DOE/RL-2016-09 Rev. 0)). Note plume areas and corresponding estimated plume volumes are (highly) positively correlated.

b. Use available information (e.g., environmental impact statements, risk assessments) to evaluate.

c. Based on aquifer tube data or contours exceeding the threshold from the Hanford Environmental Information System (HEIS).

Figure D.1-2. Decision logic for rating threats to the Columbia River from groundwater contaminants (where steps in red box are for current impacts and those below are for potential future impacts to the river).

1.1. GROUNDWATER CONTAMINANT PLUMES ASSOCIATED WITH EACH EVALUATION UNIT

Figure D.1-3 provides an overview of all the primary groundwater contaminant plumes present within the Hanford Site, which are further grouped into three groundwater EUs along the River Corridor and two groundwater EUs in the Central Plateau. Figure D.1-4 focuses on the Central Plateau groundwater plumes and Figure D.1-5 provides a simplified version of the Central Plateau groundwater plumes (excluding nitrate and tritium) in the 200 East Area (EU CP-GW-1) and 200 West Area (EU CP-GW-2) that includes only the Group A primary contaminants (high mobility and high persistence including Tc-99, I-129, C-14, Cl-36, Cr(VI), and carbon tetrachloride) and Group B primary contaminants (high mobility with medium persistence, including cyanide and TCE; and medium mobility with high or medium persistence, including U(total), Cr(total), and Sr-90).

An overview of the River Corridor groundwater contaminant plumes are provided in Figure D.1-6, Figure D.1-7 and Figure D.1-8. Figure D.1-6 is enlarged to show an example of the intersection of the existing groundwater plume with the riparian zone (magenta cross hatch area) and also provides the primary contaminant groupings, plume areas, and applicable water quality standards (AWS).

1.2. REFERENCES

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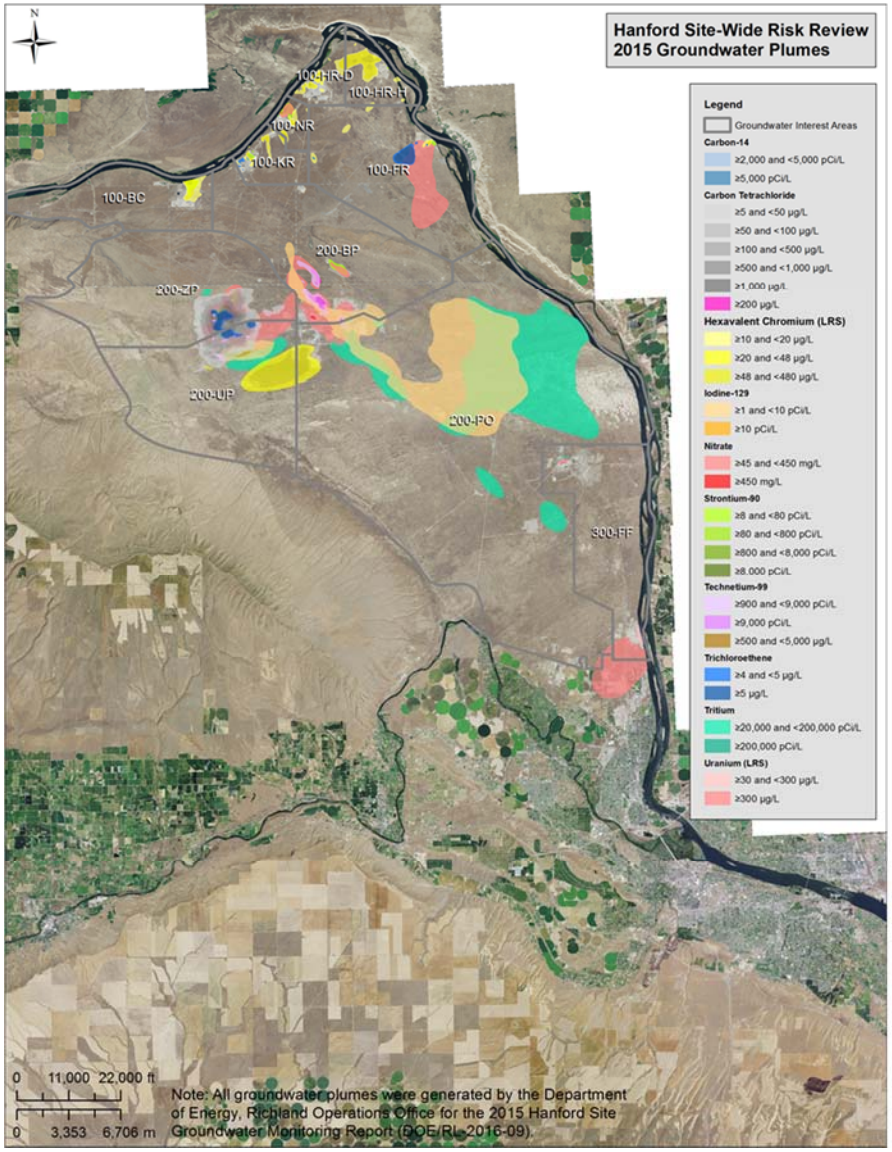


Hanford Plumes

River Corridor

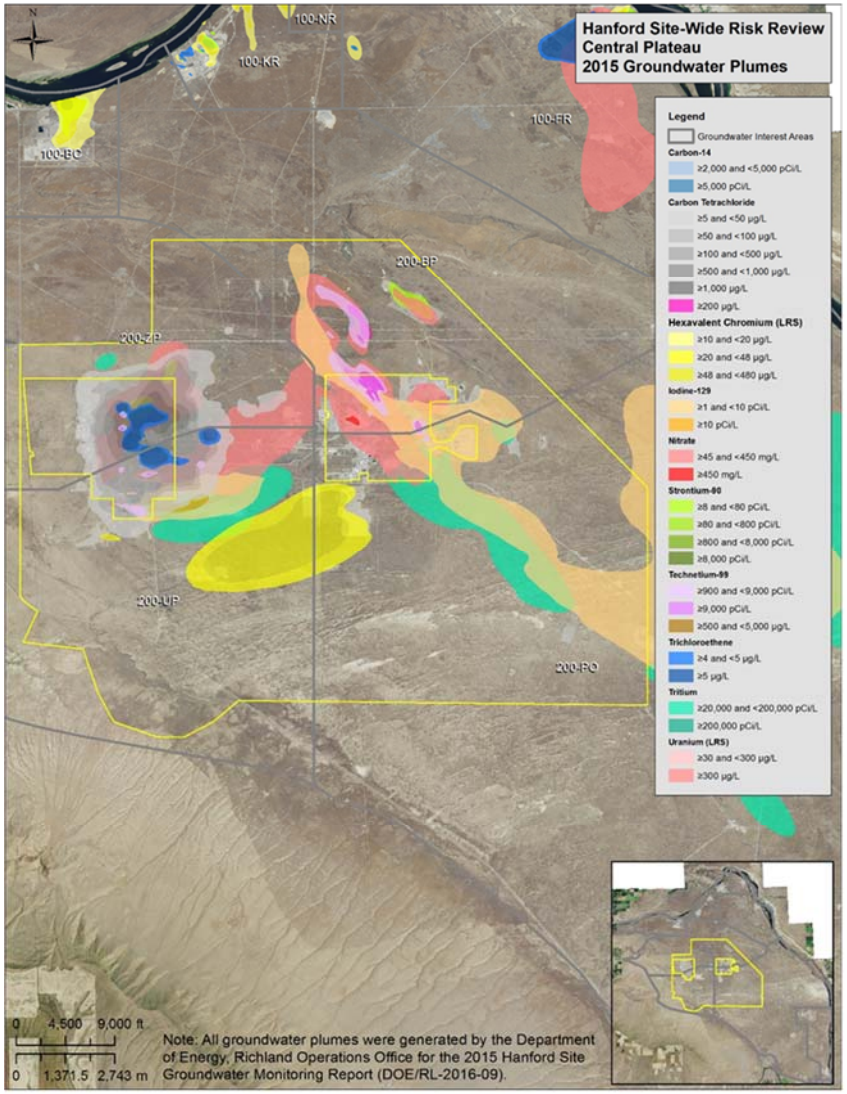
100-BC, 100-KR, 100-HR-D & -H
(chromium, strontium-90, others)
100-NR (strontium-90)
300-FF (uranium)

Central Plateau

200 West Groundwater –
200-ZP and 200-UP IAs
(carbon tetrachloride,
technetium-99)

200 East Groundwater –
200-BP and 200-PO IAs
(iodine-129, tritium)

Figure D.1-3. Groundwater plumes at the Hanford Site based on 2015 groundwater monitoring data and listing of Evaluation Unit (EU) and corresponding interest area (IA) designations.



CP-GW-1 (200 East GW EUs)

PC	Grp	WQS	200-BP Area (km²)	200-PO Area (km²)
H-3	C	2E4 pCi/L	0.1	69.5
I-129	A	1 pCi/L	5.5	54.8
NO_3	C	45 mg/L	8.2	2.1
Tc-99	A	900 pCi/L	2.1	0.06
Sr-90	B	8 pCi/L	0.6	<0.01
U (tot)	B	30 µg/L	0.6	0.04
CN	B	200 µg/L	0.7	---

CP-GW-2 (200 West GW EUs)

PC	Grp	WQS	200-ZP Area (km²)	200-UP Area (km²)
CCl_4	A	5 µg/L	18	
NO_3	C	45 mg/L	7.2	5.7
H-3	C	2E4 pCi/L	0.20	5.4
Cr-VI	A	48 µg/L	0.6	5.7
I-129	A	1 pCi/L	0.09	3.5
TCE	B	5 µg/L	1.13	---
U (tot)	B	30 µg/L	---	0.3
Tc-99	A	900 pCi/L	0.06	0.3

Figure D.1-4. Central Plateau groundwater plumes (200 E, 200 W and Central Plateau indicated by yellow outlines), plume areas, PC groups and applicable WQS.

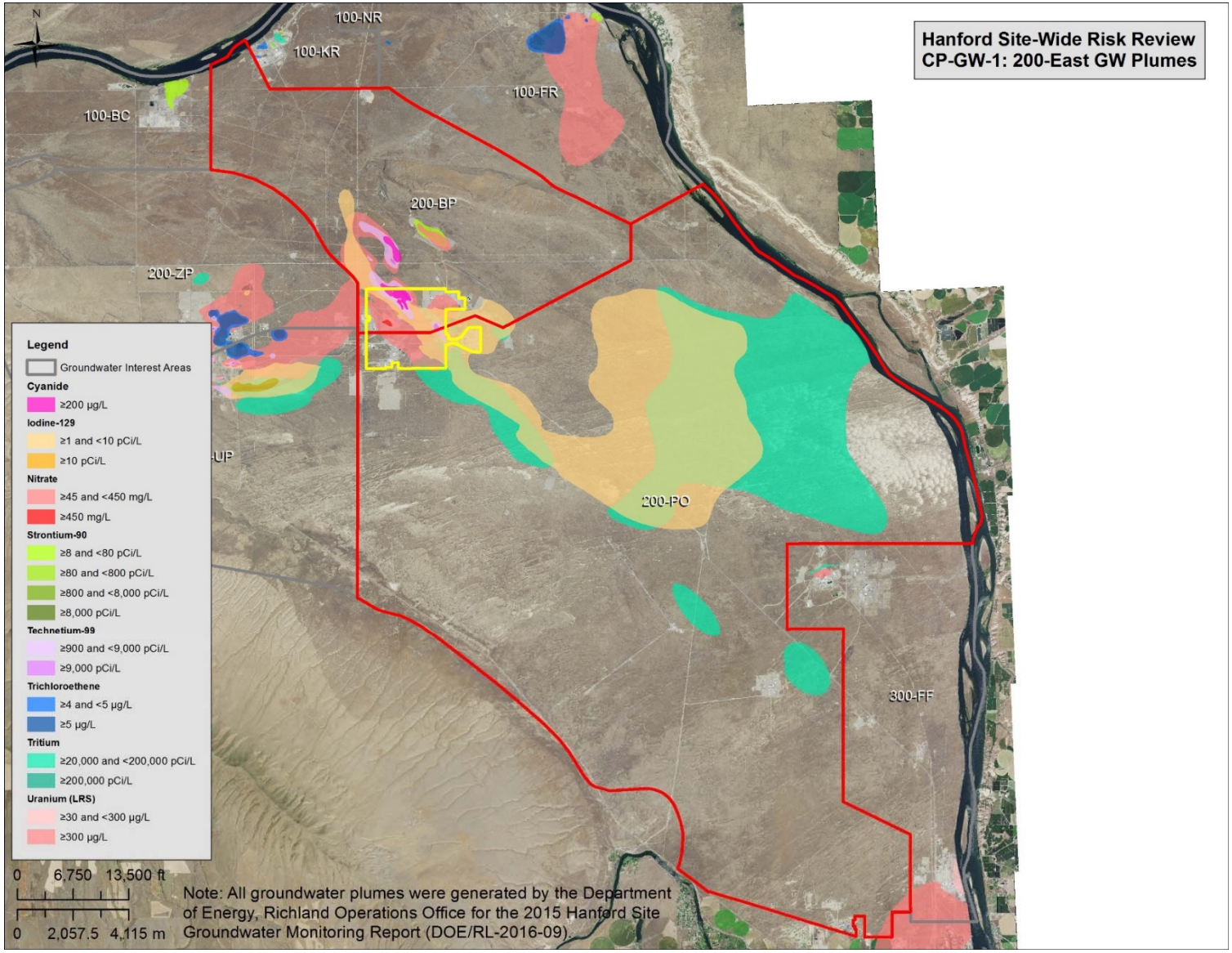
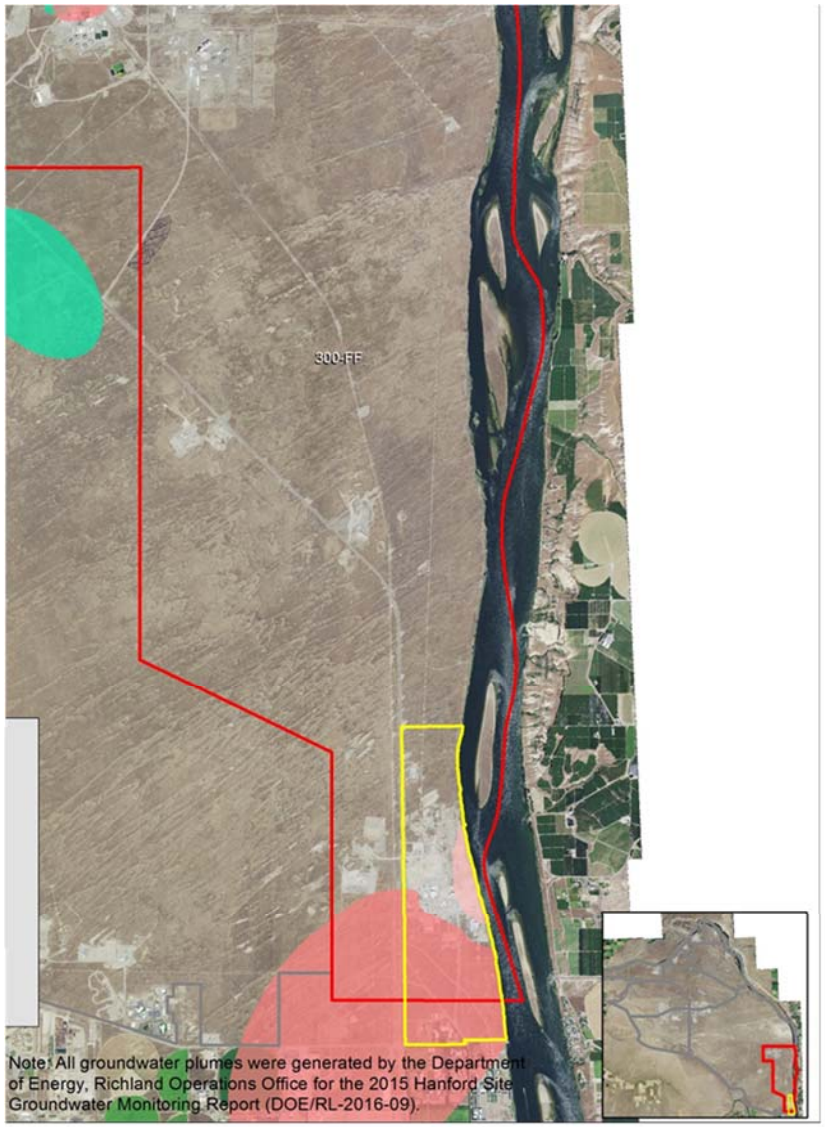


Figure D.1-5. 200 East Area groundwater plumes (EU: CP-GW-1) and 200 West Area groundwater plumes (EU: CP-GW-2) based on 2015 groundwater monitoring data, excluding tritium and nitrate. 200 East Area is indicated by the yellow outline.



PC	Grp	WQS	RC-GW-1 300-FF Area (km^2)	RC-GW-2 100-NR Area (km^2)
Cr-VI	A	10 µg/L	---	0.49
Sr-90	B	8 pCi/L	---	0.64
U (tot)	B	30 µg/L	0.34	---
H-3	C	2E4 pCi/L	0.12	---
NO_3	C	45 mg/L	0.18	0.55

PC	Grp	WQS	RC-GW-3 100-BC Area (km^2)	RC-GW-3 100-HR Area (km^2)
Cr-VI	A	48 µg/L	1.6	4.8
Sr-90	B	8 pCi/L	0.55	0.02
NO_3	C	45 mg/L	---	0.0

PC	Grp	WQS	RC-GW-3 100-FR Area (km^2)	RC-GW-3 100-KR Area (km^2)
NO_3	C	45 mg/L	9.7	<0.01
Cr-VI	A	48 µg/L	0.21	1.5
TCE	B	5 µg/L	1.4	0.0
Sr-90	B	8 pCi/L	0.13	0.0
C-14	A	2000 pCi/L	---	0.0
H-3	C	2E4 pCi/L	---	0.0

Figure D.1-6. 300 Area groundwater plume map (EU: RC-GW-1) indicating intersection with the riparian zone along with Columbia River plume areas, PC groups and applicable WQS.

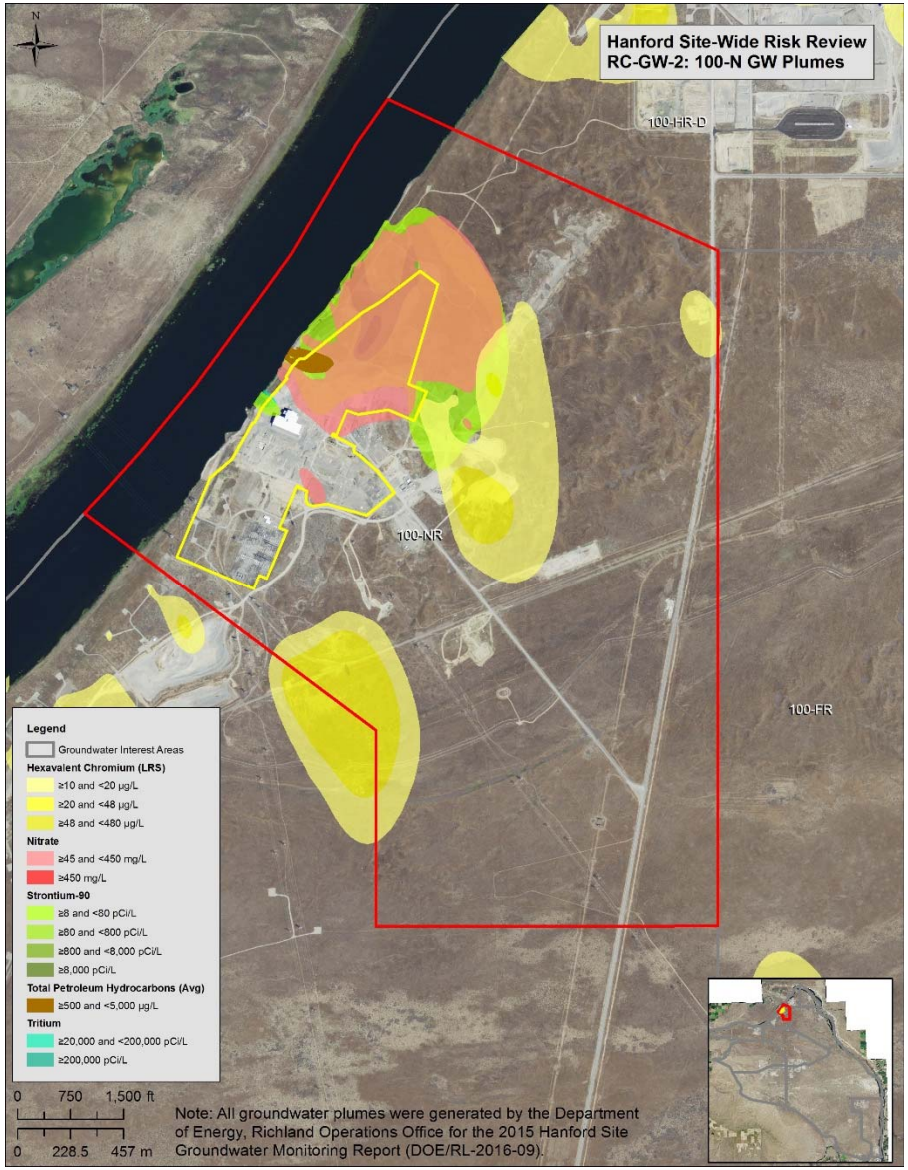


Figure D.1-7. 100-N Area River Corridor groundwater plumes (EU: RC-GW-2, based on 2015 monitoring data; riparian zone not indicated).

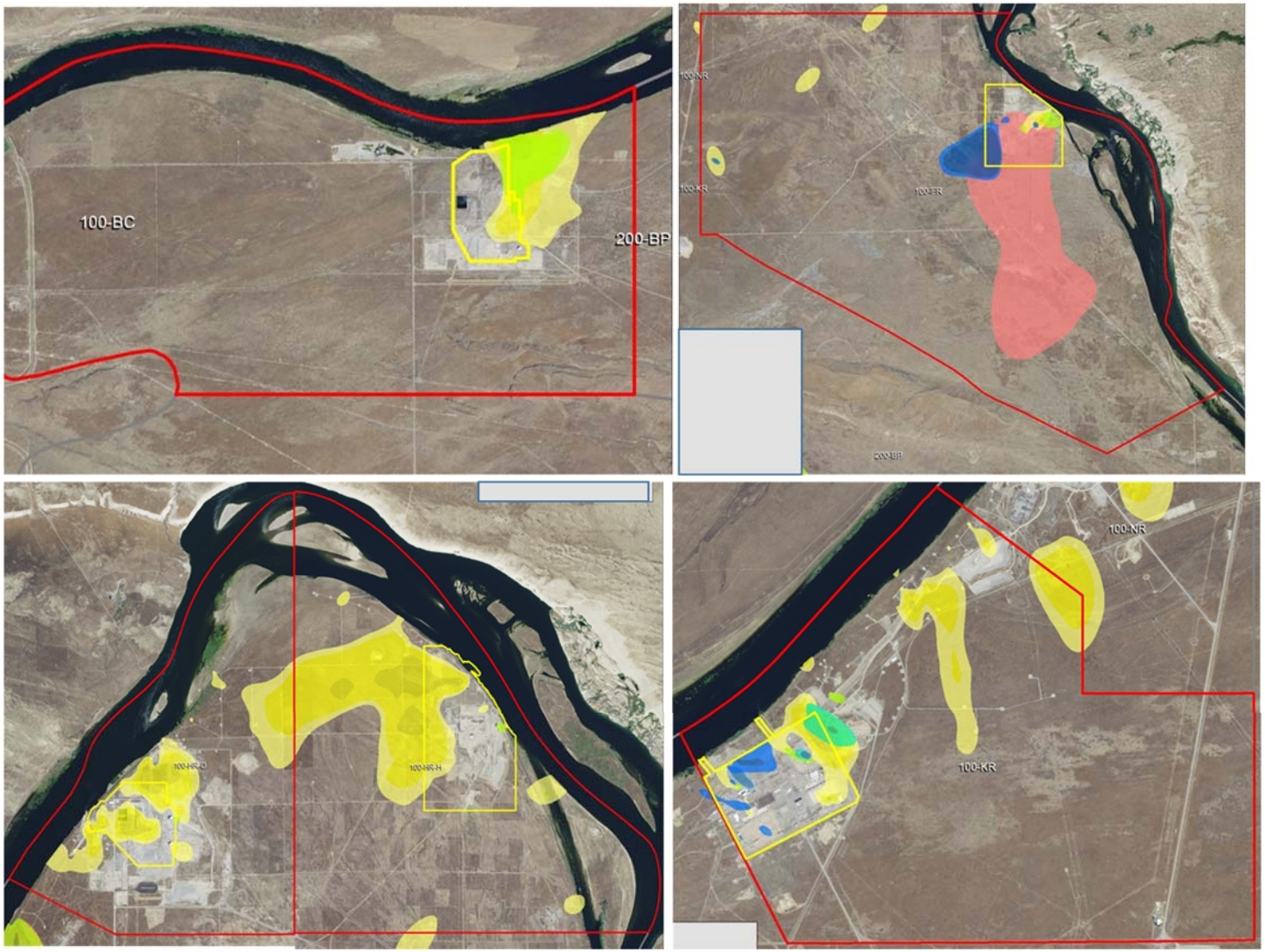


Figure D.1-8. 100-B/D/H/F/K Area groundwater plumes (EU: RC-GW-3, based on 2015 monitoring data; riparian zone not indicated)